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Quarterly Technical Progress Report

No. 6329-12

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

March 31, 1983

Contract 956205

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Approved by:

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Manager, Advanced Programs

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Sylmar, California 91342

May 1983

The JPL Flat Plate Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

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ABSTRACT/SUMMARY

The use of CO in place of H_2 for the reducing step did not appreciably increase solderability of interconnects. Cells were also made printing the pastes on top of ITO coatings. Some of these cells were the best electrically but the metallization was still not adhering. Sequential use of H_2 and CO had no effect on adhesion (or lack of it).

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Section 1.0

INTRODUCTION

The objective of this contract is the optimization, evaluation, and demonstration of novel metallization applied by a screen-printing process. The process will be evaluated on both CZ and non-CZ silicon wafers.

Section 2.0

TECHNICAL DISCUSSION

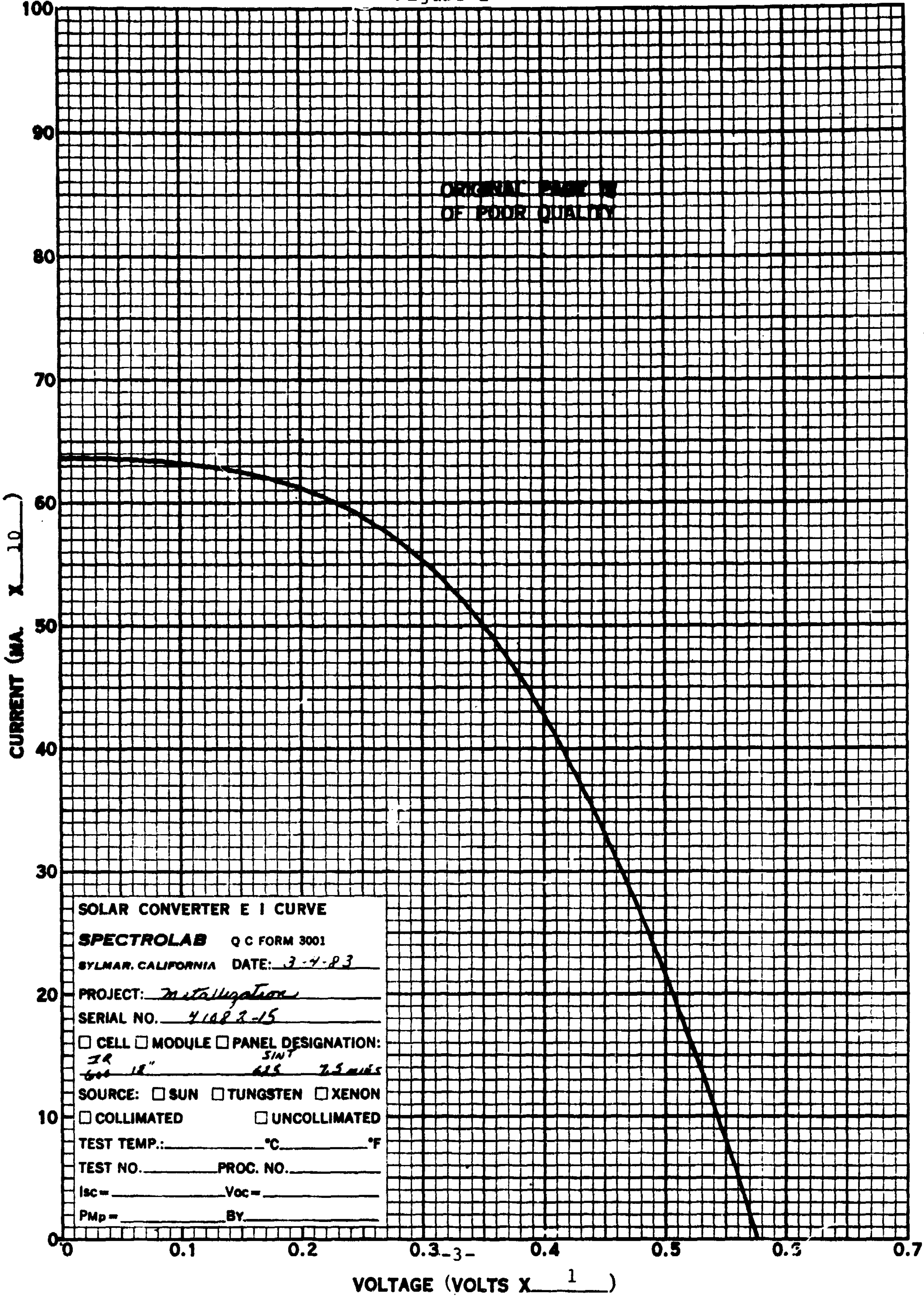
Carbon monoxide has been plumbed into the reducing furnace, allowing the use of either hydrogen or carbon monoxide. Several experiments have been run using the CO.

Carbon monoxide reductions were done after oxidative firings at both 550 and 600°C. There was little difference between the results. The cells were then fired at 550, 600, 625, 650, and 700°C. All cells showed high series resistance and poor curve shape. Figure 1 shows a typical cell air-fired at 600°C 18"/min. and reduced at 625°C for 7.5 minutes. These conditions seemed optimum but the characteristics are unacceptable. There was no appreciable lowering of the shunt resistance even when temperatures of 700°C were reached. Figure 2 shows a cell reduced at 700°C for 10 minutes where little shunting has occurred. Reducing for longer times at lower temperatures increased the series resistance as is seen in Figure 3. Cells fired at the longer times (>15 min.) also had small tin globules formed on the surface.

All cells made with the Type F paste (Pb/borosilicate frit) passed tape-pull tests. Cells made with the Type A paste failed. Soldering was alway unsuccessful.

Wafers were coated with indium tin oxide (ITO) prior to metallization. The ITO was applied using reactive sputtering by Applied Film Labs Inc. The thickness varied from 512 to 783Å with an

Figure 1



ORIGINAL PAGE IS OF POOR QUALITY
CURRENT (MA. X 10)
VOLTAGE (VOLTS X 1)
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 3-4-83
PROJECT: Metallization
SERIAL NO. 41082-15
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 2

ORIGINAL PAGE IS OF POOR QUALITY

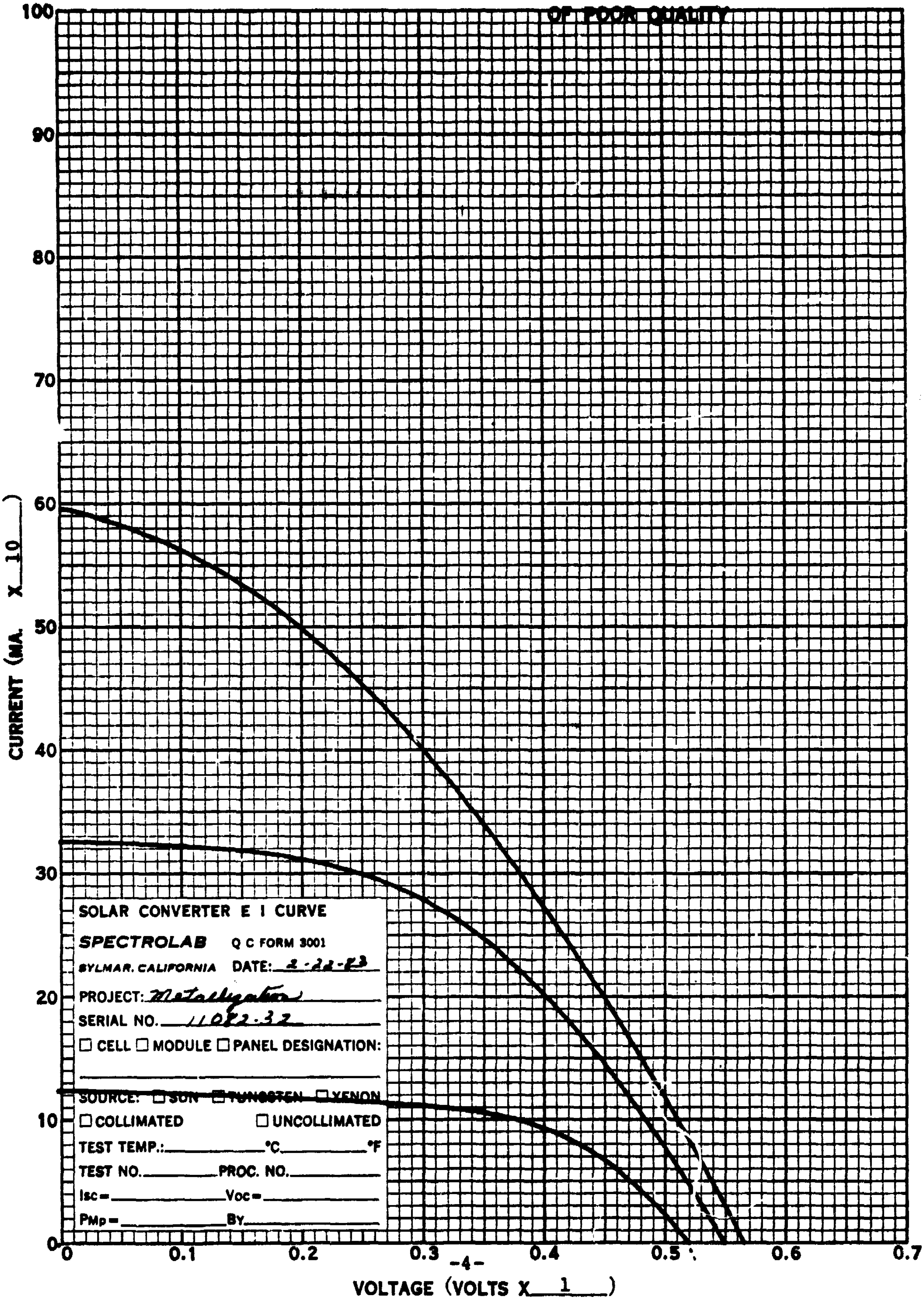
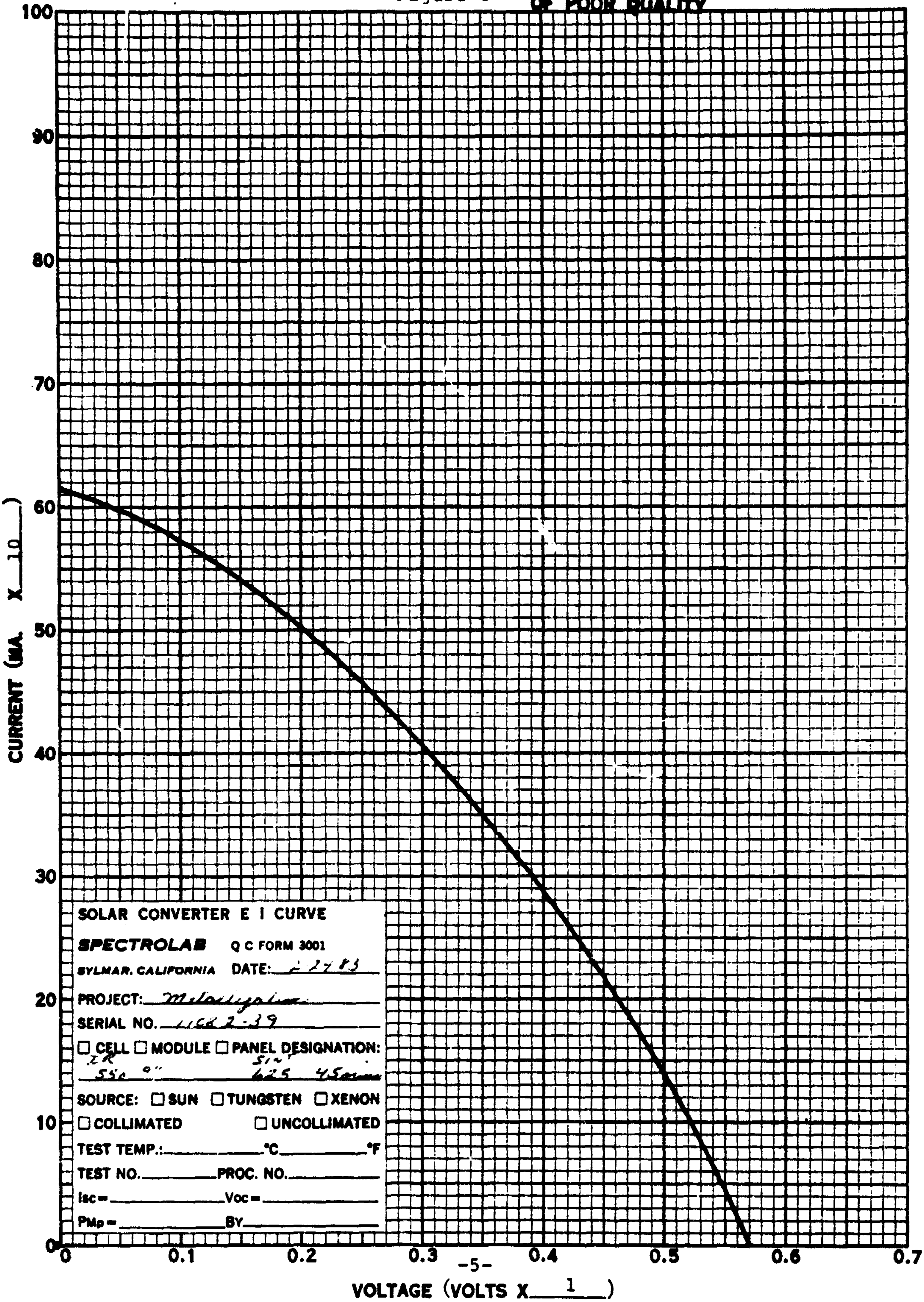


Figure 3


CURRENT (MA. X 10)
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80
70
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40
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20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO.
CELL MODULE PANEL DESIGNATION:
SOURCE: SUN TUNGSTEN XENON
COLLIMATED UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

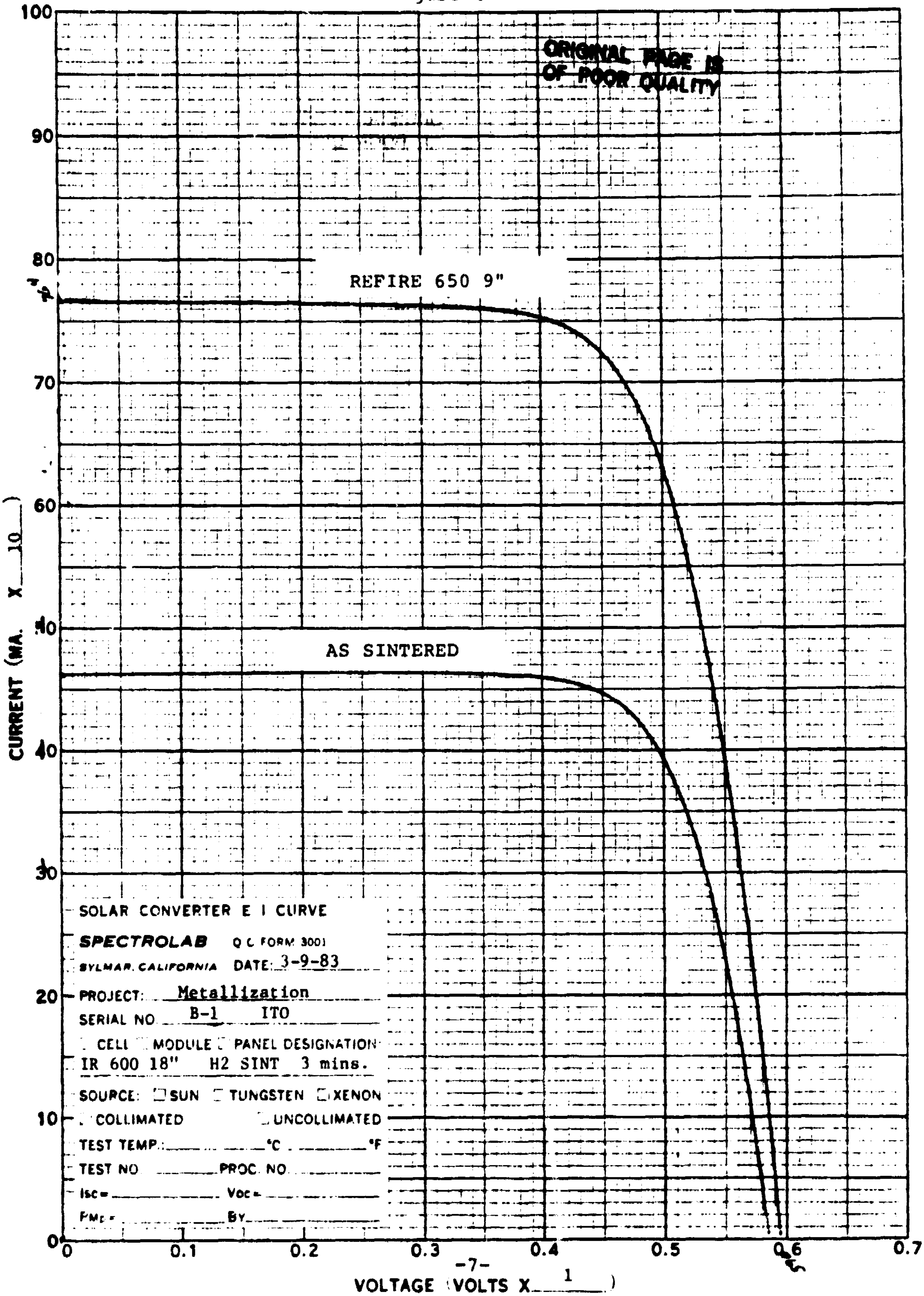
index of refraction of ∿1.95. The reflected color varied with increasing thickness as follows: green bronze, bronze, purple, blue. The cells were reduced using hydrogen at 600°C. The hydrogen firing also reduced the ITO causing a milky appearance on the cells. Air firing of the cell brought back some of the color of the film and improved cell performance as is shown in Figure 4. Attempts to fire the cells at 650°C led to severe shunting, Figure 5. The particle-to-particle adhesion for the ITO cells was still not adequate for soldering.

Several cells were made by screen printing silver paste over the ITO. Figure 6 shows these cells as compared with a conventionally AR coated silver cell. ITO does not appear to be as effective an AR coating as the conventional SiO. This may be due to incorrect thickness, lower index of refraction, or absorption in the ITO.

A group of cells were reduced sequentially in CO and hydrogen and vice versa. These cells showed excellent electrical characteristics similar to H_2 reduced cells but were still unsolderable.

In another experiment a paste was made by adding 3% #3347 silver paste (Thick Film Systems) to the Type F paste. This paste was then used with both CO and H_2 reductions. These cells were also unsolderable.

Figure 4


ORIGINAL PAGE IS OF POOR QUALITY
REFIRE 650 9"
AS SINTERED
CURRENT (MA. X 10)
VOLTAGE (VOLTS X 1)
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80
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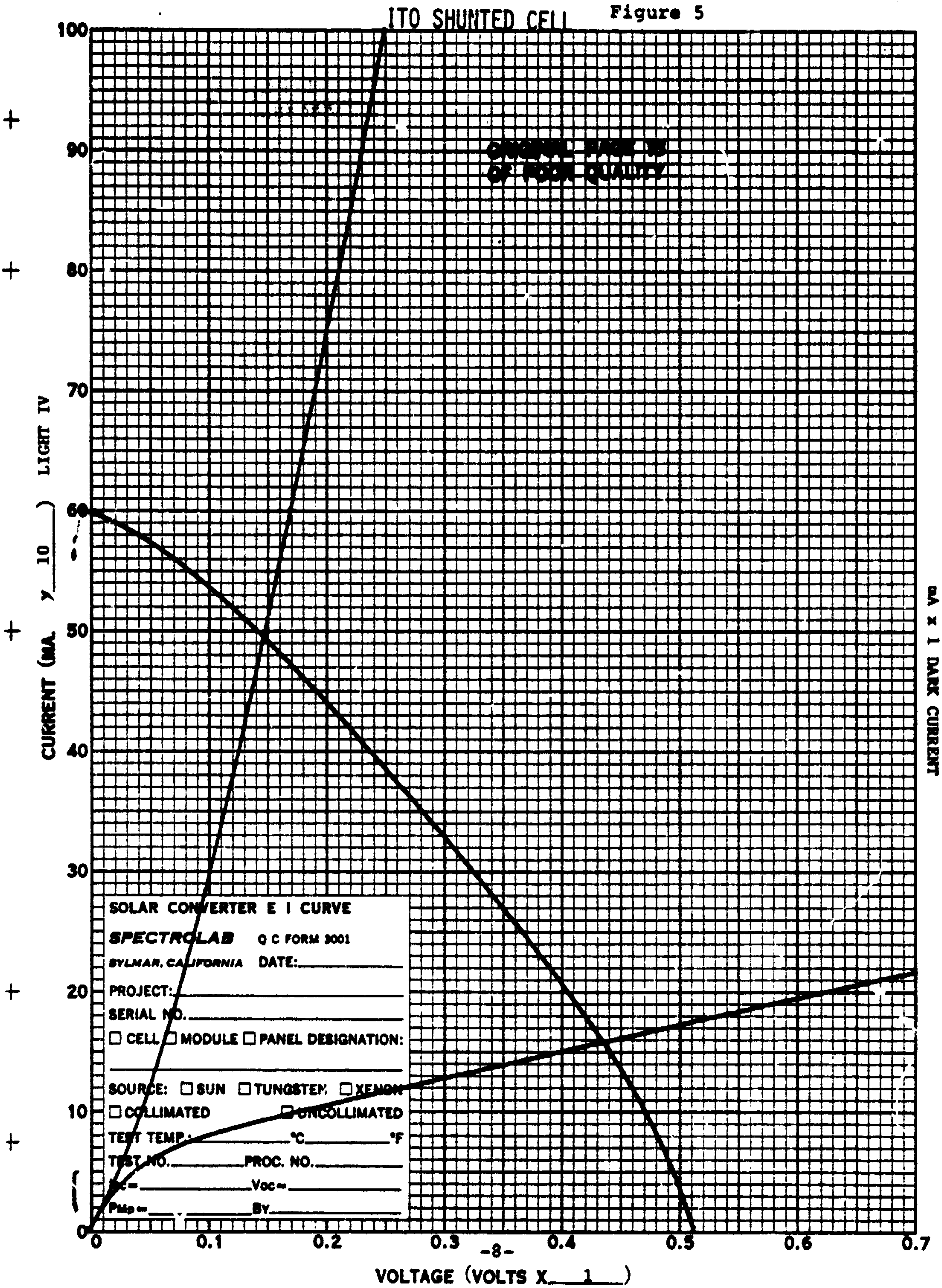
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 3-9-83
PROJECT: Metallization
SERIAL NO B-1 ITO
CELL MODULE PANEL DESIGNATION
IR 600 18" H2 SINT 3 mins.
SOURCE: SUN TUNGSTEN XENON
COLLIMATED UNCOLLIMATED
TEST TEMP. °C °F
TEST NO PROC. NO
Isc = Voc =
Pmp = BY

Figure 5


ITO SHUNTED CELL
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OF POOR QUALITY
CURRENT (MA. X 10) LIGHT IV
MA x 1 DARK CURRENT
VOLTAGE (VOLTS X 1)
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60
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90
100
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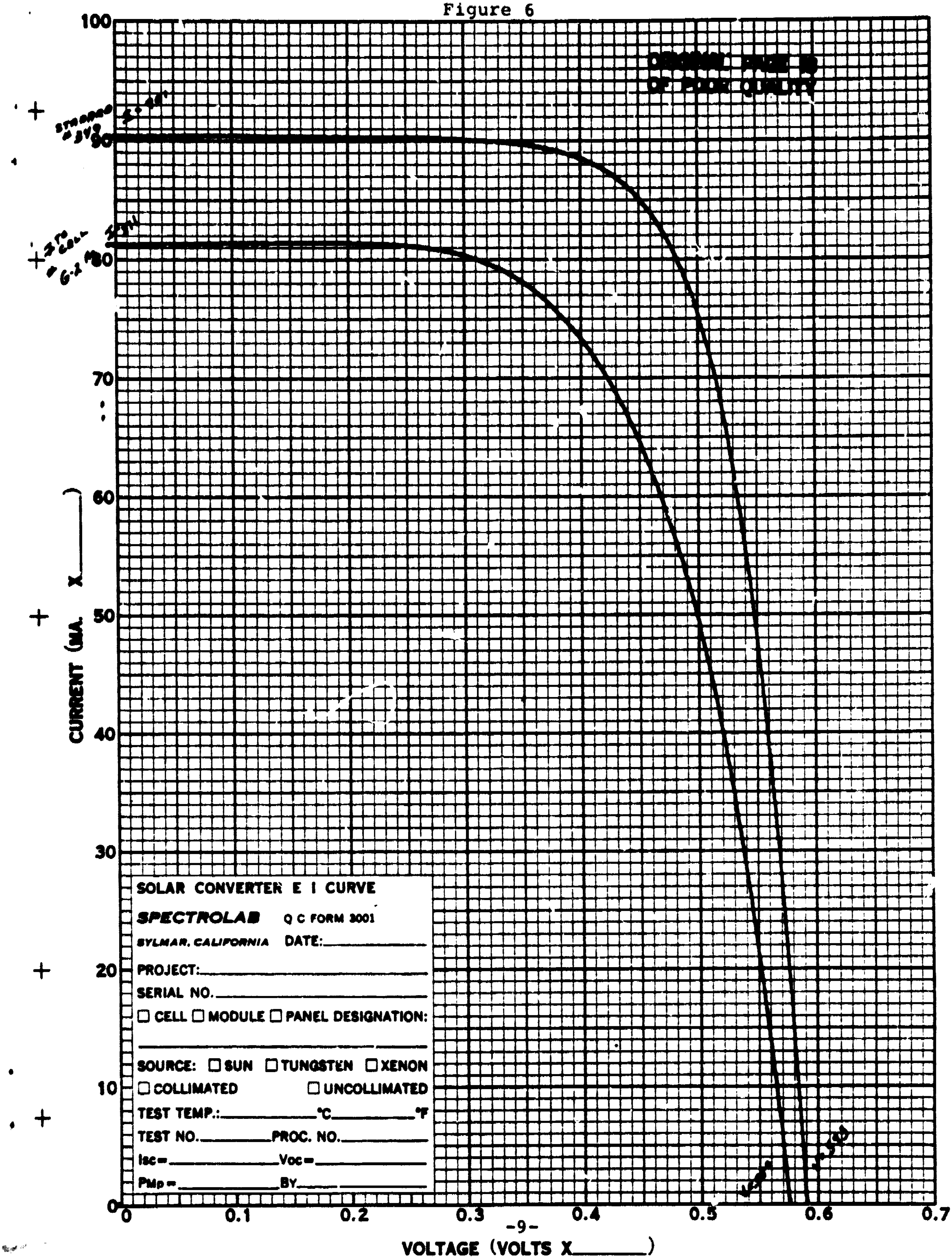
0.3
0.4
0.5
0.6
0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO.
CELL MODULE PANEL DESIGNATION:
SOURCE: SUN TUNGSTEN XENON
COLLIMATED UNCOLLIMATED
TEST TEMP. °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMP = BY

Figure 6



CURRENT (MA. X
VOLTAGE (VOLTS X)
0
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0.1
0.2
0.3
0.4
0.5
0.6
0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB
Q C FORM 3001
SYLMAR, CALIFORNIA
DATE:
PROJECT:
SERIAL NO.
CELL
MODULE
PANEL DESIGNATION:
SOURCE:
SUN
TUNGSTEN
XENON
COLLIMATED
UNCOLLIMATED
TEST TEMP.:
°C
°F
TEST NO.
PROC. NO.
Isc=
Voc=
PMP=
BY

Section 3.0

CONCLUSIONS AND RECOMMENDATIONS

Work will continue on solving the adhesion problem between the pastes and silicon which preclude the successful solder of interconnects to the cell.

Section 4.0

ACTIVITIES PROJECTION

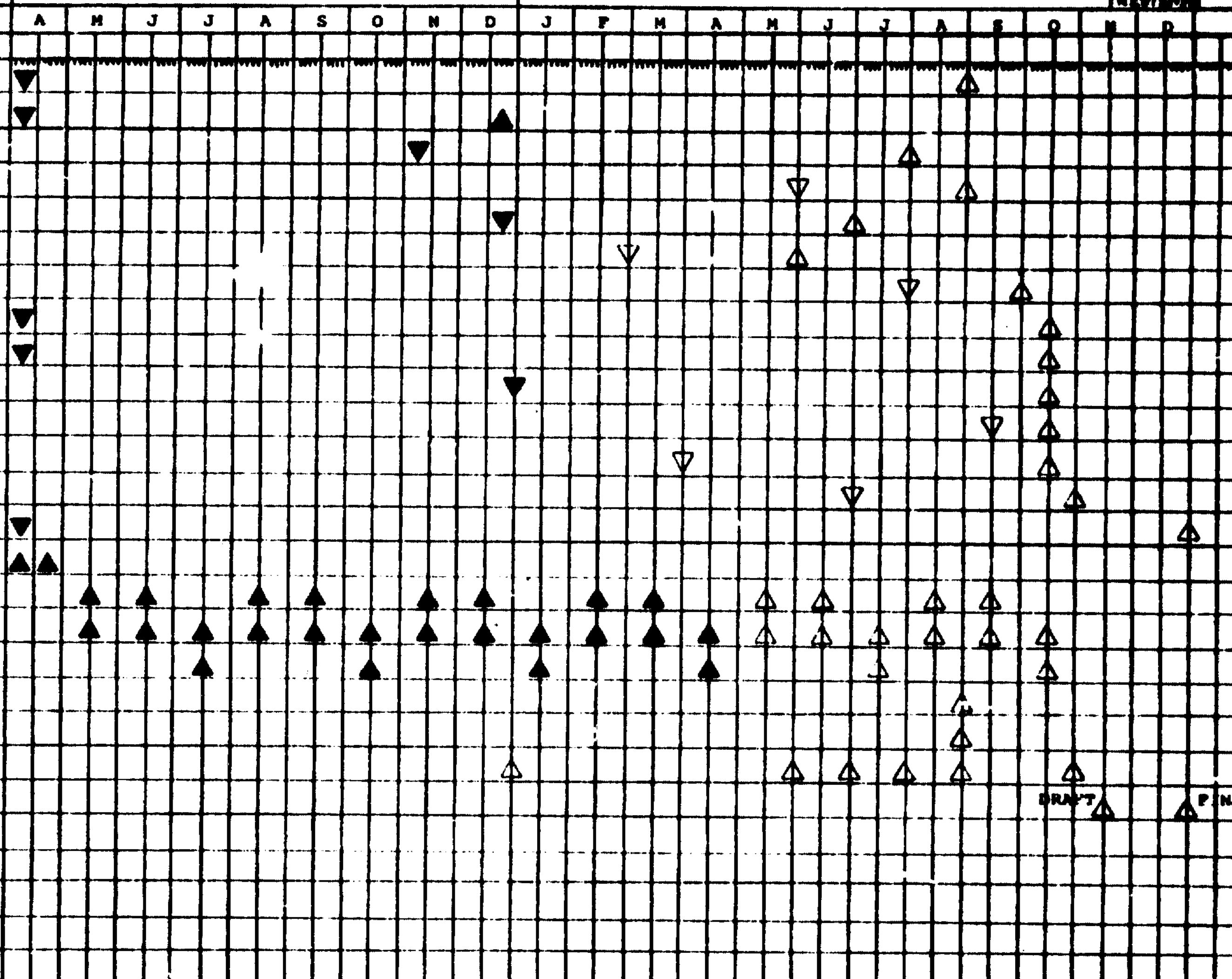
A revised program plan and milestone chart was developed concurrently with JPL personnel. This milestone chart follows:

SPECTROLAB
a subsidiary of Hughes Aircraft Co

MILESTONE CHART AND DELIVERY SCHEDULE

SHEET 1 OF 1
DATE 4/13/83
REVISION

ITEM OR TASK	DESCRIPTION
10	FRONT METALLIZATION
11	Initial Formulation
12	Re-Formulations
13	ITO on Metal
14	Metal on ITO
15	Two Step Process
20	DEMONSTRATION RUN & EVALUATION
30	TESTING
31	Electrical Characteristics
32	Adhesion
33	Humidity
34	Contact Resistance
40	NON-CZ PROCESSES
50	MANAGEMENT
	Program Plan
	Monthly Technical Report
	Monthly Financial Report
	Quarterly Technical Report
	Process Specifications
	Economic Evaluation
	Prototype Cell Deliveries
	Final Report



LEGEND

NOTES

CUSTOMER JET PROPULSION LABORATORY

PROGRAM -7- METALLIZATION

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